LS-2
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Light Source Job List and Plan - Part I

The following description is what we would like to do, and as our work progresses, these descriptions would change as the whole scheme is put together. This note is intended to describe our current thinking and to show interconnections of various subtasks.

1. Storage Ring Group

A. Refinement of Lattice

a. Photons from Bending Magnets

It appears that extracting photons from a bending magnet has some difficulties. Of two dipoles in each cell, the downstream magnet does not pose difficulties, but the other one does. If all 64 bending magnets are to be equipped with the photon beamlines, the lattice arrangement may have to be adjusted.

b. Dynamic Aperture Studies

Studies done so far indicate that the Twiss functions which provide a large dynamic aperture can be found rather easily when those functions are such that they would give somewhat larger natural emittance. The lattice described in LS-1 gives the natural emittance of $\sim$ 8 x 10^{-9} m. We need refinement of this lattice with εxo $\sim$ 7 x 10^{-9} m and same time would give larger dynamic aperture.

What we need here is to streamline the computing process to find the solutions systematically. Once such a computing system is set up and debugged, we can utilize off-hour computing either at HEP VAX or CSD low priority computing. This task was discussed with S. Kramer on October 5, 1984.

c. Refinement of Accelerator Physics Straight Section

Four straight sections set aside for accelerator needs have to be refined. Two of these are for the rf system which requires low β straight sections for beam stability reasons. For injection straight section, it is preferred to have controlled orbit deformation within a straight section in order to avoid effect of machine tune to orbit deformation and thus bumper magnet settings. Then the preferred scheme is to use four bump magnets to move the closed orbit to near inflector (EC October 5, 1984).

B. Non-standard Lattice

There are two separate items which need to be pursued: one is to make an eight-sided machine with each sector containing one 12 m straight section, and the other is to investigate the possibility of rearranging the damping partition numbers so that the natural emittance could be made smaller. Doing the latter part may involve introduction of gradient magnets in the lattice. This needs extreme care because Albert Hofman had looked at this scheme for the ESRP. (EC,YC).

C. Touschek Lifetime

This is one area where there is a standard theory, however application of theory depends on the assumptions used. For this reason there will be a separate note covering the detail of this calculation for our own discussion.

The lattice described in LS-1 has a Touschek lifetime of 44.6 hours when it is run with all undulator mode and a single bunch current of 9.4 mA or single bunch population of 1.5×10^{11} particles. This means that this lifetime is applicable for 94 mA and 10 bunches, 188 mA for 20 bunches, and so on provided that there is no other effect prevent in doing so.

D. Gas Scattering Lifetime

There are several formalisms that exist to handle this effect, and there seems to be some minor variations of the formulae which treat the gas effect with averaged machine parameters. However we should treat this effect with the machine parameters of each element rather than with the average values. Reasons for advocating this method are: the extreme aperture limits come from descete set of undulators (8 mm x 8 mm), and to incorporate H. Wiedman’s idea that we do not need very good vacuum in the area where the beta functions are smaller. (TK)

E. BBI (Bunched Beam Instabilities)

We shall follow standard bunched beam instabilities calculation using estimated coupling impedances from various ring components. Some of these impedance inputs shall be obtained from cavity mode calculations to be performed in conjunction with rf system design.

F. Magnet Error Considerations

The Standard method of handling position errors, field errors and gradient errors must be applied to set construction and placement criteria of each element. Magnet designers should provide expected higher pole components of magnets to be used in the tracking.

G. Tracking of Particles

Computer simulations of particle tracking in the storage ring with some realistic imperfections of machine components built into a model storage ring must be done in order to insure large dynamic apertures available for storage mode as well as injection mode. Once bare machine tracking is done, then we can further pursue studies of effects of the insertion device to machine as well as the effects of one insertion device to another.

H. <u>Orthongonal Adjustments of Beam Positions and Angles</u>

Since there are 32-4 straight sections, and 64 bending magnets, it is possible to install 92 beam ports in the storage ring. Furthermore due to the fact that the photon beamline can be many tens of meters long, it may be necessary to adjust the source point positions and emission angles of photon for each beam port independent of all others. A brute force method of handling this situation is to install some 736 steering magnets to accommodate this. Design task is to investigate the method by which we can reduce this number. For example, what do we gain if we use backleg windings of the ring dipole.

2. Injector Group

Areas to be covered by this group include a 6 GeV synchrotron, a positron accumulator ring, positron production target, and all associated transport lines. The repetition rate of the injector synchrotron should be matched with positron production and accumulation rate. Since we need to reserve 20% upgrade capacity, the peak field of the magnet should not exceed 7 ∼ 8 K Gauss. The idea that we could use similar bending magnets as that of the storage ring was explored but abandoned due to the fact that the injector synchrotron can be made compact. If we were to accumulate and to inject a few bunches at a time from, the synchrotron to the storage, then the usual constraint of having an integer ratio of the circumferences can be relaxed. In this case, the circumference of each ring should be so designed to accommodate same rf frequency.

The injection field strength of the synchrotron can be as low as a few hundred Gauss, however the value of this field will be decided by positron energy.

As for a positron accumulation system, there are a couple of examples of existing systems such as PIA at DESY. Thus the feasibility of such a system is not in question. However what needs to be studied is a relationship between the repetition rate of the injector synchrotron and the positron linac energy. For example, PIA operates at 450 MeV and the DESY synchrotron at a few HZ rep rate. Could we lower the positron energy from 450 MeV to 300 MeV and raise the rep rate of the synchrotron to achieve the same accumulation rate?

Another important topic this group should provide is energy, current, pulse length and rep rate of the electron beam which is to be used to generate the positron. Is electron energy of 70 ∼ 100 MeV enough? If so, then what current is needed? These values will be needed to refine the linac. The starting values of the electron linac can be 70 MeV, 2 μ sec pulse length, 100 mA peak current, and 50 Hz rep rate. Since performance of the positron accumulation dictates the linac performance, we must decide these values as soon as possible.

3. Linac Group

This group is to design both electron and positron linac systems. As mentioned above, the performance goal will be decided by the positron accumulation rate.

Since these kinds of linacs are available commercially in Europe and in Japan, we must look into such possibility.

4. rf Group

This group's task includes design of the rf system for both injector synchrotron and storage ring. At this time we should mainly be concerned with the high power portion of the system rather than extending ourselves into the low level portion which can be studied some later date. With respect to power handling capability, this group needs input from the Storage Ring Group as well as from the Insertion Device Group. At this moment we contemplate using 500 Mhz system a la PETRA or KEK. However 350 Mhz system of PEP and ERSP should be considered. For the purpose of expanding bunch length as well as for the purpose of Landau damping, we should consider and make provision for adding a third harmonic cavity.

For cavity design and eigen-mode calculation we should use computer code URMEL and its associated programs which investigate beam-cavity interactions. Estimated shunt impedances will be needed to calculate the Bunched Beam Instabilities.

5. Alignment and Stability

This task includes providing quick surveying methods of the storage ring components, beamline elements, etc. This group is to provide both external and internal beam position feedback system. Doing so involves specifications of sensitivities of various position monitoring systems. This implies this should be an extremely close communications with storage lattice designers and the technical component designers.

Another extremely important task which needs to be carried out is the mechanical and seismic stabilities. It is hoped that drifting of the beam with a time constant larger than the synchrotron damping time can be removed by feedback systems.

6. Technical Components

The immediate task needed to be accomplished by this group is to design the magnets based on the magnet parameters described in the LS-1 note. Any refinement we can add later on to the final lattice would not change the magnet design substantially. It is worthwhile to note here that almost all of the electron storage rings, regardless of operating energy, have similar apertures. The reason for this is that for the electron ring the physical aperture is not dictated by the circulating beam sizes.

Since we must extract photon beams from the insertion devices as well as the bending magnets, the dipoles should be "C" magnets which would facilitate transportation of both kinds of beam. The following table shows some examples of gap dimensions.

	V	H
ESR	65 mm	190 mm
PEP	70 mm	210 mm
ESRP(78)	50 mm	130 mm
ALS	65 mm	140 mm

We propose here that as a starting point, we use the gap dimension of 140 mm x 65 mm, then ask ourselves if the horizontal width of 140 mm is good enough to provide a dynamic aperture of some 40 σ's.

Here, one train of thought we would like to try to impose, if possible, is to avoid discontinuities of vacuum chamber dimensions. Having such discontinuities imposes very elaborated transition pieces of the vacuum chambers as done on many existing machines.

With this idea in mind we would propose to design the lattice quadrupoles with aperture diameter of 65 mm. Some subset of the quadrupoles may have to be narrow quadrupoles or "C" type quadrupole in order to provide the photon beam extraction channel. Examples of bore size of existing machines are shown below.

CESR	80 mm dia.
PEP	120 mm dia.
ERSP(78)	80 mm dia.

Similar comments and remarks can be made for the chromaticity sextupoles, and "C" type sextupoles may be needed to extract the photon beams from the upstream bending magnet of each period.

As we can surmise, the idea that imposing 65 mm gap height of dipoles to the bore diameters of the quadrupoles and sextupoles seems to be a good idea, but two other physics argument may have to substantiate this point. One point is the transverse coupling impedance is proportional to $R/_{b}{}^{2}$, where R is the average radius of the storage rind and b is bore radius. This means that for smaller b Z_T becomes large. The other is the dynamic aperture.

7. Vacuum

As we know, vacuum systems can cause many difficulties for electron storage rings. To avoid this it is planned to store the positrons. However we must not neglect the importance of a good vacuum system. Usage of positron eliminates the ion trapping problems, but we may face other problems such as e^+e^- annihilations, pressure bump phenomena. These are unlikely but we need clear answers.

Although reaching 10^{-9} torr or better, the vacuum is straight forward for the unloaded machine, photodisorption by synchrotron radiation provides extreme difficulties in reaching such a pressure.

Questions needed to be answered are:

a. Chamber materials (SS, $A\ell$, Cu-A_u alloy, etc.)

To answer this, input must include baking of chamber, cleaning glow discharge, ease of construction including exit port of light and antechamber if needed, and pumping method.

b. Heat deposition of chamber-wall by radiation

This information is needed to calculate cooling capacity and to devise a radiation catcher which may be worthwhile to devise because the bending magnet radiation would hit certain local areas such as just downstream. To do this a special version of computer code TURTLE is suggested to calculate the local distribution or radiation depositions.

c. Photon beam extraction channels from the insertion devices as well as from bending magnets. This implies very close communication with the magnet designers.

8. Diagnostics

This group is to provide diagnostics systems for the entire system starting from the electron gun to the photon beam lines. Task includes to provide sufficient information to facilitate the external beam feedbacks and orthogonol adjustments of the beam positions as well and emission angles. To do so we must investigate existing systems at Fermilab, PEP, PETRA, CESR, etc.

9. Control System

Computer architecture should include processing of all information to operate the overall accelerator system as well as the beam manipulations discussed in various sections described herein.